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Not just text: using Micron's Automata Processor in particle physics research

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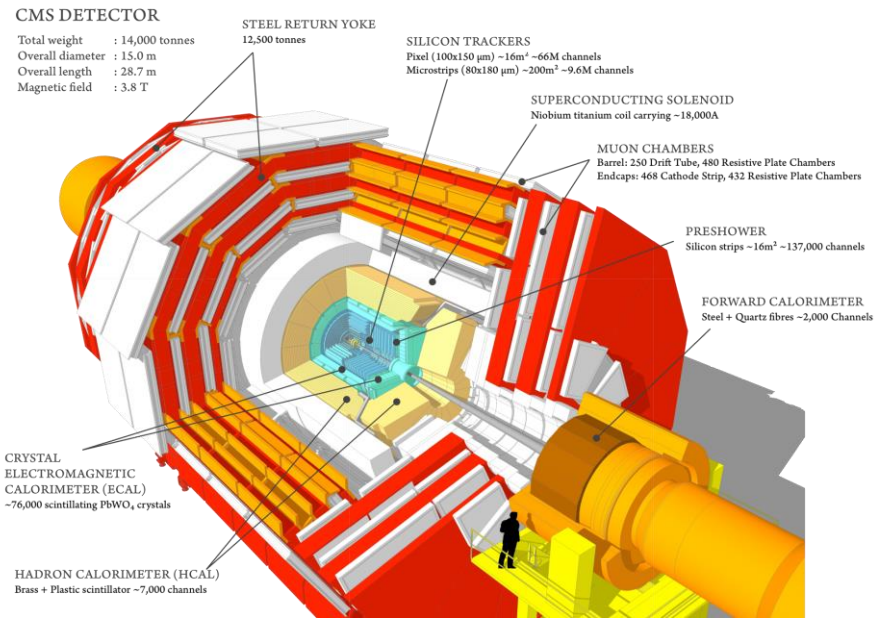
SC15, Austin, TX.

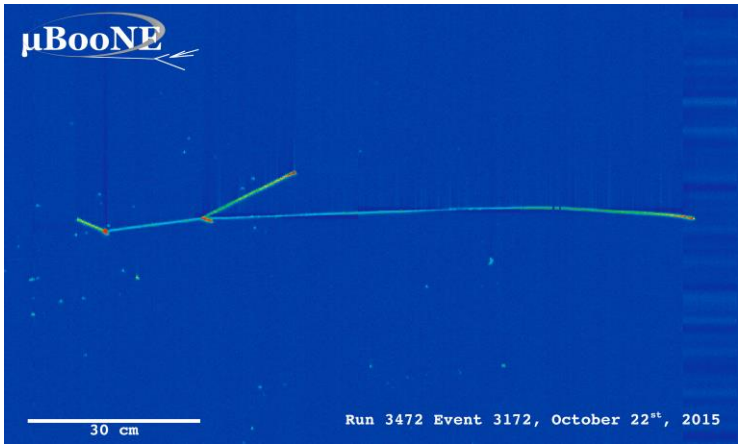
Nov 18, 2015.

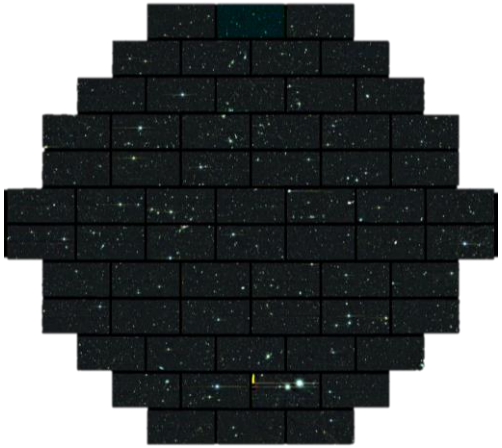
Particle Physics and Fermilab

Study fundamental particles and interactions to understand the nature of matter and energy:

- “Big-Bang recreation.”
- Neutrino physics.
- Structure and formation of the Universe.







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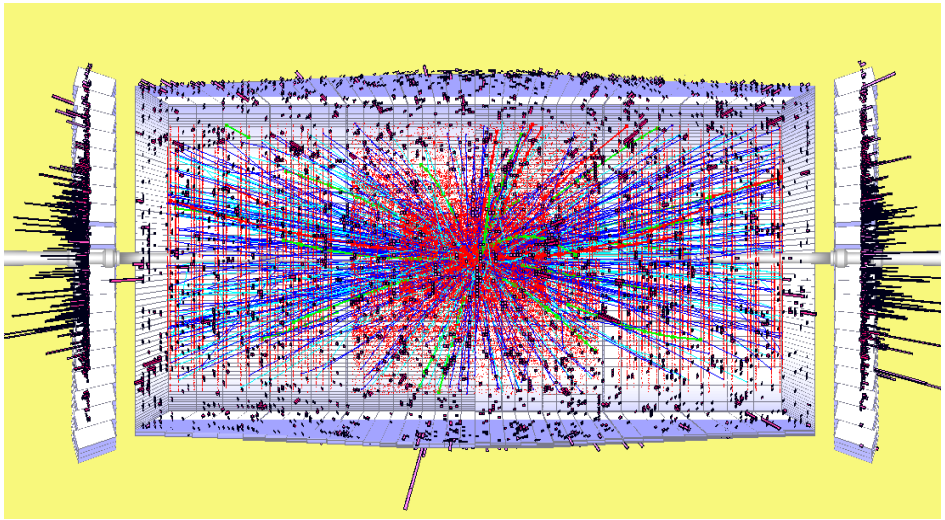
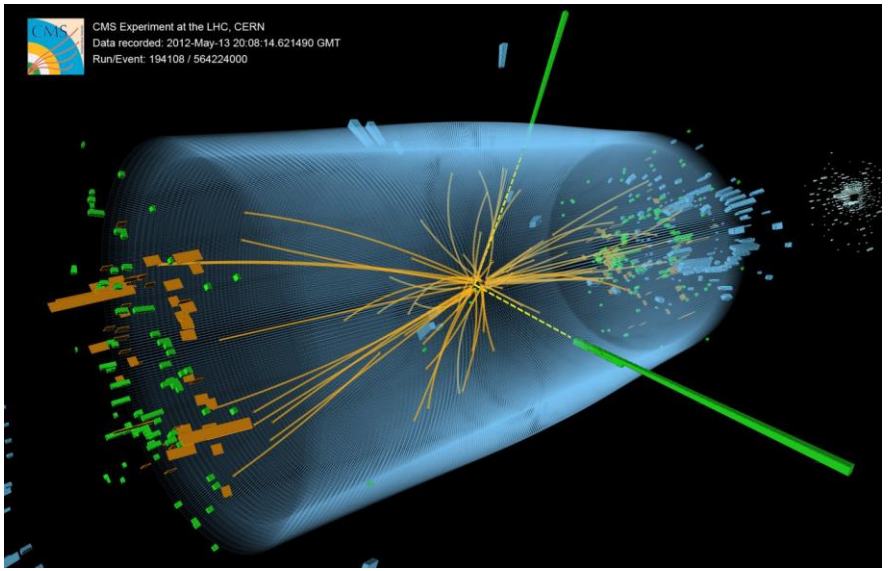
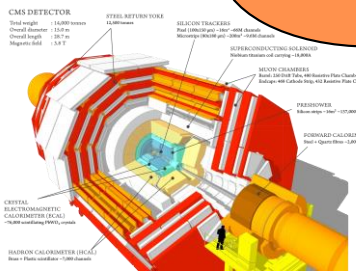
Anatomy of a particle-physics experiment

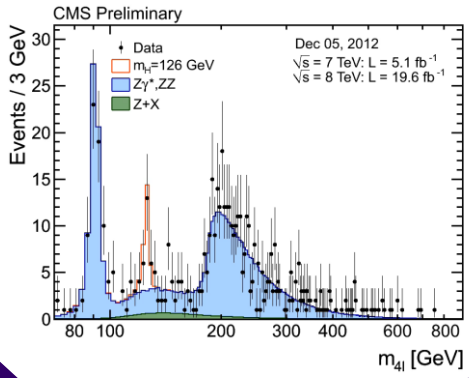
- Needle-in-haystack: need 100T collisions to see 1 Higgs!
- Lots of data: >20PiB/y from CMS alone.
- High rates: 40M collisions/sec, each with around 140 (mostly boring) simultaneous interactions in phase II (planning for 5+ years from now).
- Some detectors read out more slowly, and can't keep every event, so two-tier trigger required.

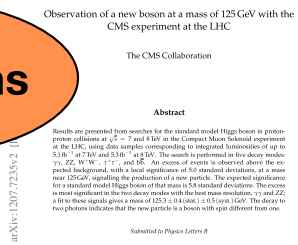




Anatomy of a particle-physics experiment






EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CMS-HIG-12-028

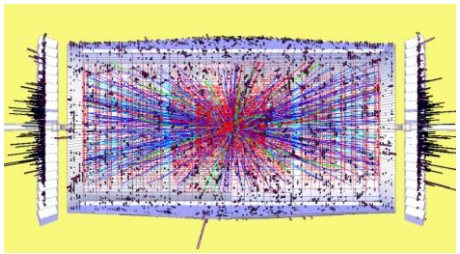
Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC

The CMS Collaboration

Abstract

Results are presented from searches for the standard model Higgs boson in proton-proton collisions at $\sqrt{s}$ = 7 and 8 TeV in the Compact Muon Solenoid experiment at the LHC, using data samples corresponding to integrated luminosities of up to 5.1 fb^{-1} at 7 TeV and 5.3 fb^{-1} at 8 TeV. The search is performed in five decay modes: $\gamma\gamma$, ZZ, W$^+$W$^-$, $\tau^+\tau^-$, and $b\bar{b}$. An excess of events is observed above the expected background, with a local significance of 5σ standard deviations, at a mass near 125 GeV, signalling the production of a new particle. The expected significance for a standard model Higgs boson of that mass is 5.8 standard deviations. The excess is most significant in the two decay modes with the best mass resolution, $\gamma\gamma$ and ZZ; a fit to these signals gives a mass of 125.3 ± 0.4 (stat.) ± 0.5 (syst.) GeV. The decay to two photons indicates that the new particle is a boson with spin different from one.

Submitted to Physics Letters B



DAQ

Publications

Analysis

Trigger / Filter

Reconstruction

Simulation

Storage

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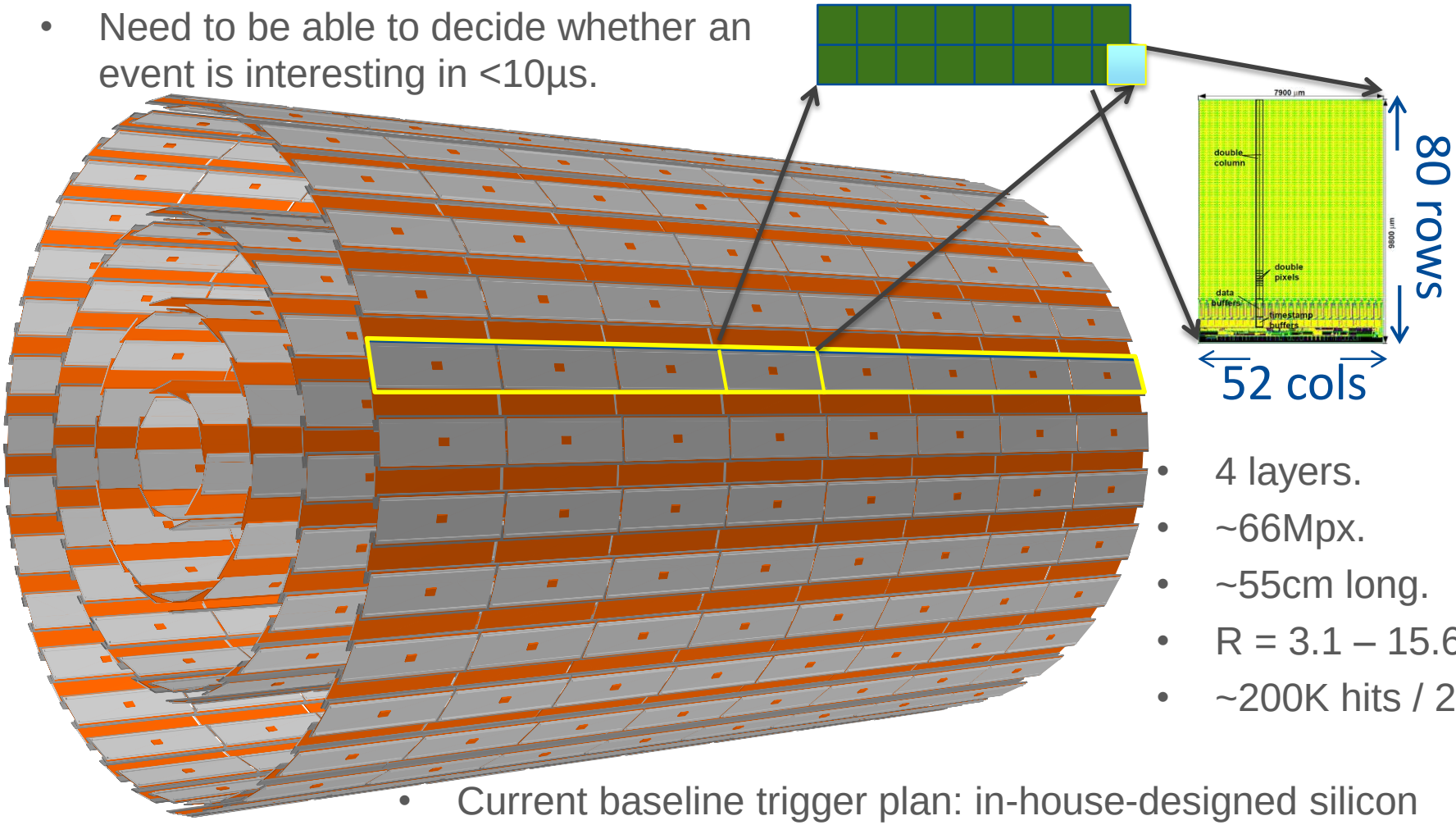
The CMS phase II Pixel detector and trigger

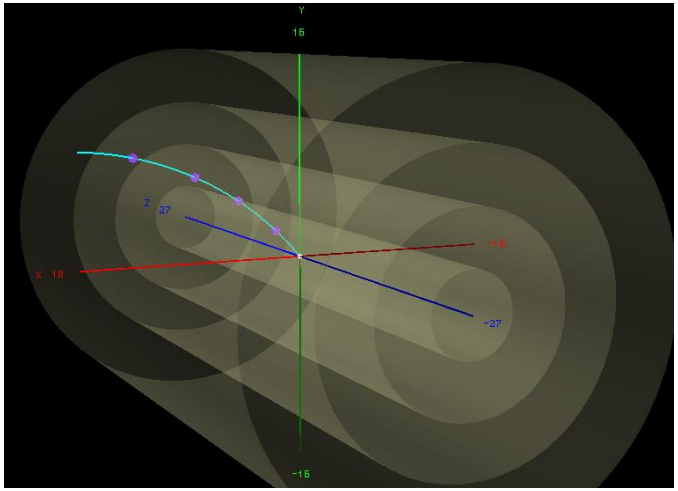
- Need to be able to decide whether an event is interesting in <10µs.



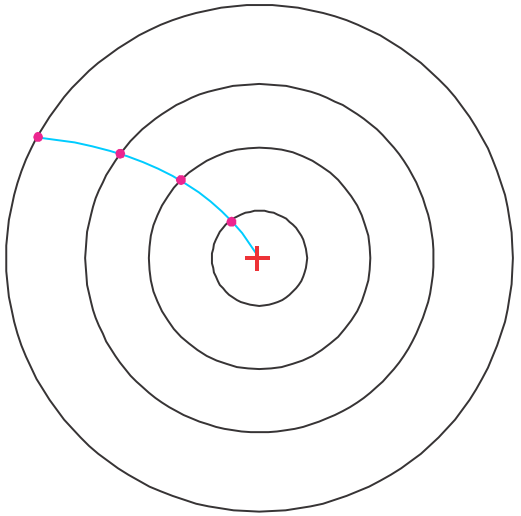
- 4 layers.
- ~66Mpx.
- ~55cm long.
- R = 3.1 – 15.6cm.
- ~200K hits / 25ns.

- Current baseline trigger plan: in-house-designed silicon using majority-logic associative memory on custom boards with ultra-high-bandwidth infrastructure: multi-year R & D.

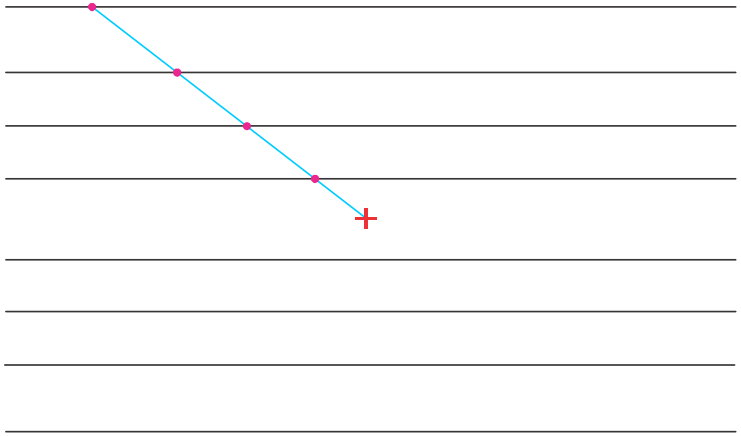
Turning physics data into a pattern recognition problem

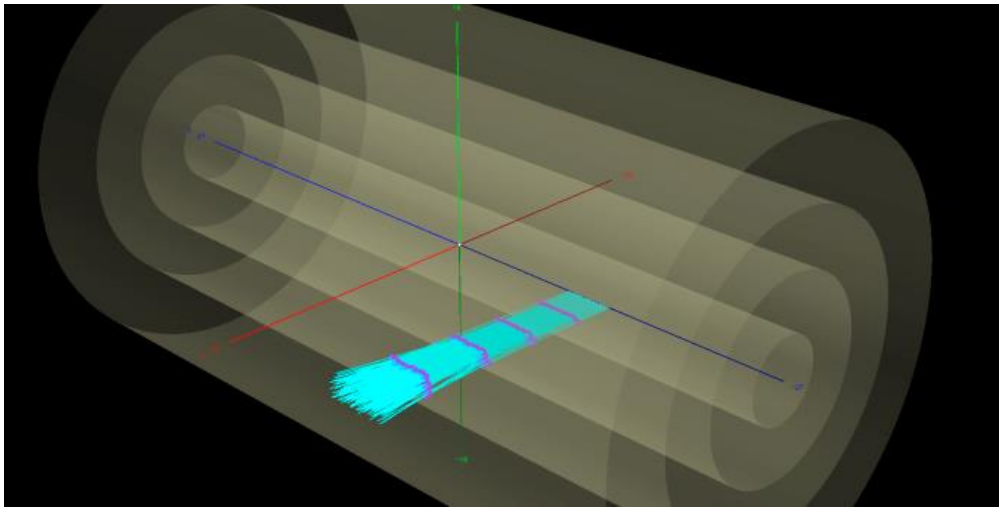


r-ø



r-z





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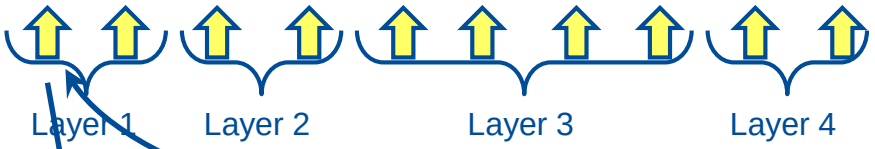
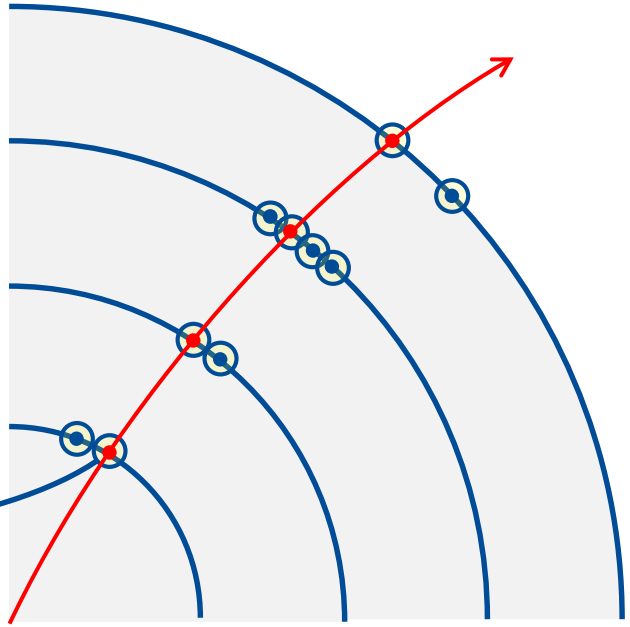
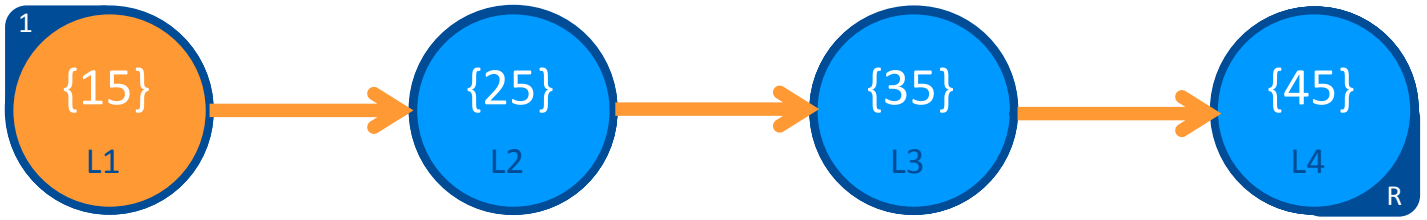
A simplified problem to start …

Address of hits in detector streaming in layer order:

15,17,23,25,31,32,35,36,41,45

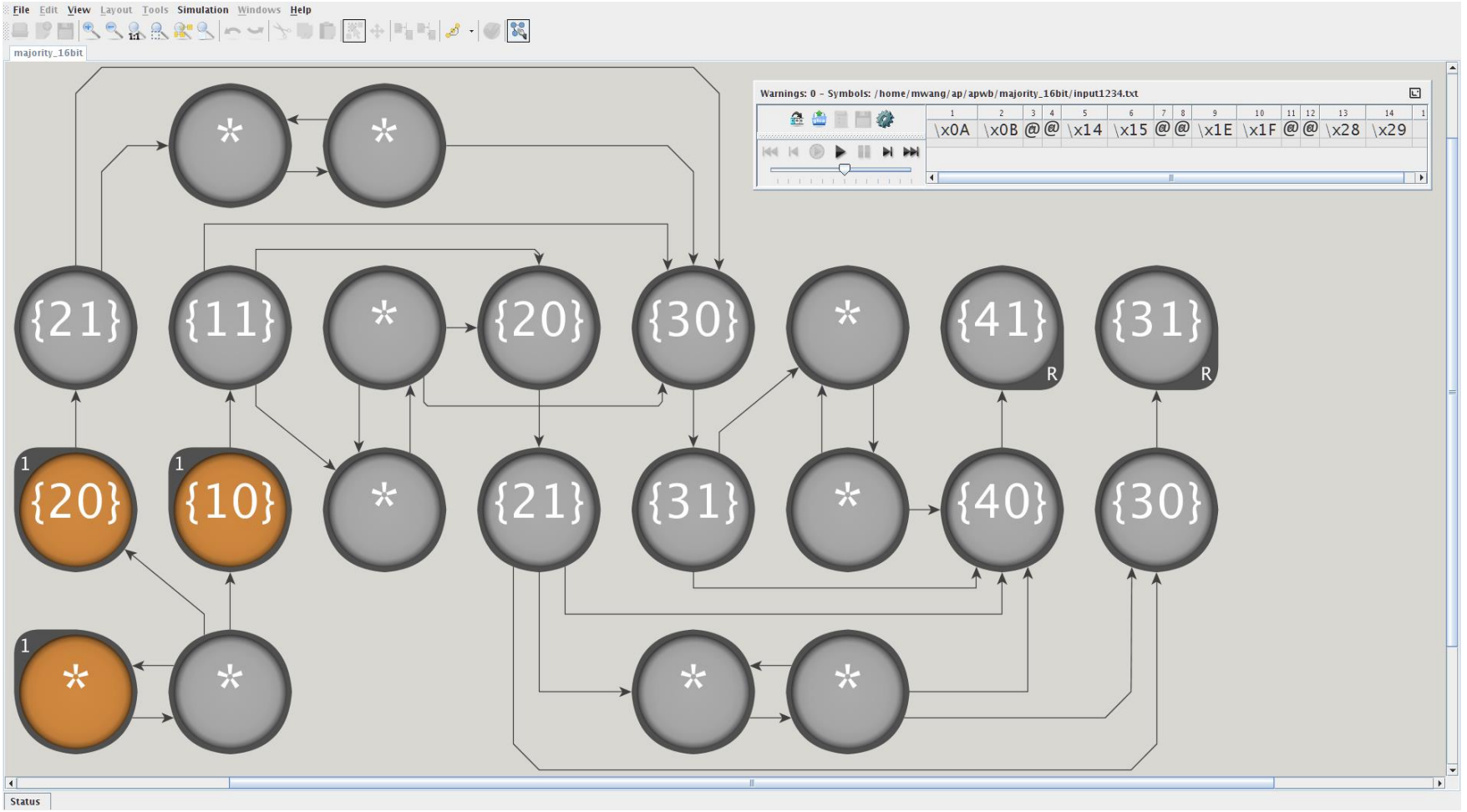






Limitations: 8-bit symbols, need latches, need all 4 hits.

An automata network to match one track pattern



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Scaling up

- Shown is a pattern matching unit for one interesting hit combination: with a grain size of 4 pixels per hit “address”, this is 419760 r-ø units and 1,137,644 r-z units.
- Exploring pattern re-use through geometric (e.g. rotational, translational, mirror) symmetries.
- Explore tradeoffs with granularity vs resource use.
- Studying readout speeds, latched results, symbol reloading.
- May be used in other areas, not just low level trigger.

Finally …

- Funded development work will also include a study of hit detection with timing in liquid argon tracking detectors for neutrino and dark matter experiments.
- Initial work looks promising: looking forward to hardware via Center for Automata Processing at the University of Virginia.
- Thanks:
  - Fermilab's LDRD program for supporting and funding this project.
  - UVA CAP, especially Kevin Skadron, Tho Nguyen, Ke Wang, Jeff Fox.
  - Micron, especially T. Leslie, M. Tanner, M. Grimm.
  - CMS, especially T. Liu, O. Gusche, D. Christian.